VISIT…

APPENDICES

Appendix A

Lubrication Program*
Work Process Manual

Lubrication Program Work Process Manual

Overview

Introduction	The purpose of this guide is to provide a detailed process for use by plants in developing, implementing, maintaining and improving their industrial lubrication programs. It is a compilation and organization of existing published material, input from maintenance and reliability professionals, and experience gained by the author during his tenure as a Reliability Engineer and consultant.
Audience	This guide is intended for all individuals who are involved with any of the four phases necessary to establish industrial lubrication programs.
Purpose	To significantly reduce the amount of time required by maintenance and reliability professionals to establish effective lubrication programs.
Program Goal	The goal of every lubrication program should be to ensure that all equipment receives and maintains the required levels of lubrication such that no equipment fails due to inadequate or improper lubrication.
Note to the Reader	The step descriptions in this manual should be read in conjunction with the work process diagrams.
In this document	This document contains the following information:

Title	See Page
Step Descriptions	3
Work Process Diagrams	Appendix A

*Source: Richard P. Ellis, Pearland, Texas (richard.ellis@armic.com)

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Step 1.1 – Create Equipment List

Purpose

To establish a preliminary list of equipment to be included in the lubrication program.

Description

Before a plant can begin implementing (or thoroughly reviewing) a lubrication program, it is necessary to create or obtain a current list of all equipment that requires lubrication. The list should include all types of equipment requiring lubrication, i.e. mobile equipment, valves, HVAC equipment, etc., and not just the usual pumps, compressors and fans.

Inputs

- process flow diagrams (PFD's)
- piping and instrument diagrams (P&ID's)
- plant maintenance files
- Computerized Maintenance Management System
- physical survey of the equipment

Outputs

A Master Lubrication Schedule with the following information completed:

- item number
- process description

Tools

- Master Lubrication Schedule template: master lubrication schedule.xls

Functions & Responsibilities

This section defines the responsibilities of each function involved in this step of the work process.

Function	Responsibilities
Maintenance	1. Using the inputs defined above, create an equipment list containing, as a minimum, the item number and process description of all equipment to be surveyed in Step 1.2.

Continued on next page

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Step 1.2 – Conduct Lubrication Survey

Purpose

To collect and record on the Master Lubrication Schedule, lubrication related equipment information that is required to make a lubricant selection.

Description

The lubrication survey will consist of a detailed lubrication inspection of all plant equipment. Each machine will be studied and its lubrication related characteristics recorded on the Master Lubrication Schedule.

Obtaining this information is time consuming and may take several days to complete a survey for a typical hydrocarbon or chemical processing plant. However, such a survey is the only way of obtaining an accurate picture of current lubrication practices and it is the basis upon which future steps to select lubricants and improve lubrication practices will be made.

Since a general knowledge of the design of a machine is required for making decisions about its lubrication requirements, it may be necessary to make frequent reference to machine drawings and OEM manuals.

Inputs

- process flow diagrams (PFD's)
- plant maintenance files
- physical survey of the equipment
- OEM manuals

Outputs

A current Master Lubrication Schedule with the following information completed:

- manufacturer
- model
- equipment orientation
- bearing type
- lubricant type (oil, grease)
- method of lubrication (bath splash, circulation system, oil mist, etc.)
- normal operating temperature
- reservoir capacity
- Horsepower
- RPM
- copies of lubricant sections out of the OEM manuals for each piece of equipment

Tools

- Master Lubrication Schedule template: master lubrication schedule.xls

Functions & Responsibilities

This section defines the responsibilities of each function involved in this step of the work process.

Function	Responsibilities
Maintenance	1. Using the inputs defined above, fill in the remaining fields on the Master Lubrication Schedule.
Equipment Manufacturer	2. Provide equipment design and configuration information as required.

Continued on next page

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Step 1.3 – Select Lubricants

Purpose

To define the recommended lubricant for each piece of equipment on the Master Lubrication Schedule.

Description

Once equipment configuration and operating conditions have been collected and organized into the Master Lubrication Schedule, review the information with your lubricant vendor and a request they provide a recommended lubricant and lubrication frequency.

Inputs

- Master Lubrication Schedule
- OEM manuals

Outputs

An updated Master Lubrication Schedule with the following information completed:

- lubricant name
- lubrication frequency

Functions & Responsibilities

This section defines the responsibilities of each function involved in this step of the work process.

Function	Responsibilities
Maintenance	1. Give a copy of the Master Lubrication Schedule and associated equipment information to your lubricant supplier and request they make lubricant recommended.
Lubricant Supplier	2. Using the information provided by maintenance, make lubricant selections for each piece of equipment on the Master Lubrication Schedule. 3. Make lubrication frequency recommendations based on equipment information and supplier experience.

Continued on next page

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Step 1.4 – Consolidate Lubricants

Purpose

To reduce the total number of lubricants used in the Lubrication Program.

Description

Once lubricants have been selected for each piece of equipment on the Master Lubrication Schedule, it is important to review the list and determine if there are opportunities to reduce the total number of lubricants that will be used in the program.

In some instances you may find that there are only a few pieces of equipment that use a particular brand or grade of lubricant, and by allowing for a change in lubricant viscosity, it is possible to eliminate the use of the lubricant entirely.

Reducing the number of lubricants has the following effect on the program:

- Reduce the number of lubricants that have to be purchased
- Reduces the number of lubricants that have to be stored
- Reduces the chance of error that the wrong lubricant will be used in a piece of equipment
- Reduces the number of lubricants that have to be documented and kept track of as part of environmental compliance

Inputs

- Master Lubrication Schedule

Outputs

- A reviewed and/or revised Master Lubrication Schedule with fewer lubricants

Functions & Responsibilities

This section defines the responsibilities of each function involved in this step of the work process.

Functions	Responsibilities
Maintenance	1. Reviews and approves the list of recommendations made by the lubricant supplier on which lubricants to eliminate from the program.
Lubricant Supplier	2. Reviews Master Lubrication Schedule for opportunities to consolidate lubricants without impacting equipment reliability.
Equipment Manufacturer	3. Provides input on changes to lubricant recommendations when requested by Maintenance or Lubricant Supplier.

Continued on next page

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Step 1.5 – Create Lubrication Manual

Purpose

To provide a place where all of the information collected for development of the Lubrication Program can be stored for future reference.

Description

The process of developing a lubrication program requires the collection of a significant amount of equipment data, usually found in disperse locations. After all the time and effort expended to locate and collect the data, it is worth while to consolidate that information into a Lubrication Manual that can be referenced over time.

Inputs

- Master Lubrication Schedule
- Copies of lubricant sections from OEM manuals
- Vendor furnished lubricant product data sheets
- Vendor furnished Material Safety Data Sheets

Outputs

An assembled Lubrication Manual with the following contents:

- Master Lubrication Scheduled sorted by tag number
- Lubricant product data sheets
- Material Safety Data Sheets
- Copies of lubricant sections from OEM manuals

Note: The storage location of the Material Safety Data Sheets is most likely dependent on the environmental and industrial hygiene policies for your particular plant. Be sure and discuss this with your Environmental Specialist and/or Industrial Hygienist.

Functions & Responsibilities

This section defines the responsibilities of each function involved in this step of the work process.

Functions	Responsibilities
Maintenance	1. Collect the material and assemble it into the Lubrication Manual. 2. Store the Lubrication Manual in the plant library.
Lubricant Supplier	3. Provide lubricant product data sheets for all lubricants in the Lubrication Program. 4. Provide Material Safety Data Sheets for all lubricants in the Lubrication Program.
EH & S	5. Provide input and direction on plant or company policies regarding storage of Material Safety Data Sheets.

Continued on next page

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Step 1.6 – Purchase Lubrication Equipment

Purpose

To generate a Lubrication Program Equipment List defining the equipment that will be required to carry out the work involved with the Lubrication Program.

Description

The processes of lubricating equipment involves the use of equipment to both store and apply lubricants as defined by the scheduled service reports generated by the Computerized Maintenance Management System (CMMS). The equipment includes items such as:

- grease guns
- bulk lubricant storage facilities
- drum handling equipment (dollies, drum tilters, bung removal tools, etc.)
- shop towels
- garden type sprayers for topping-off lube levels or oil changes

Inputs

- The consolidated Master Lubrication Schedule

Outputs

- Lubrication Program Equipment List

Functions & Responsibilities

This section defines the responsibilities of each function involved in this step of the work process.

Functions	Responsibilities
Maintenance	1. Create the Lubrication Program Equipment List to be used by purchasing to buy the necessary equipment.
Purchasing	2. Procure equipment as listed on the Lubrication Program Equipment List.

Continued on next page

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Step 1.7 – Set PM Tasks & Frequency

Purpose

To define the lubrication related tasks for each equipment item and the frequency with which the tasks are to be carried out.

Description

Prior to entering the lubrication tasks into the CMMS, it is necessary to define the frequency at which the lubrication tasks will be repeated. This information, along with the data collected in earlier steps, will be input in the CMMS and used to generate the scheduled service reports.

Inputs

- The consolidated Master Lubrication Schedule
- Lubrication Program PM Task Picklist
- OEM Manuals
- Lubricant Supplier Recommendations

Outputs

- A completed Master Lubrication Schedule with all fields necessary to generate a scheduled service report

Functions & Responsibilities

This section defines the responsibilities of each function involved in this step of the work process.

Function	Responsibilities
Maintenance	1. Using the inputs shown above, define the lubrication tasks and their frequency
Equipment Manufacturer	2. Provide input into the selection of PM tasks and frequency as requested by maintenance.
Lubricant Supplier	3. Provide input into the selection of PM tasks and frequency as requested by maintenance.

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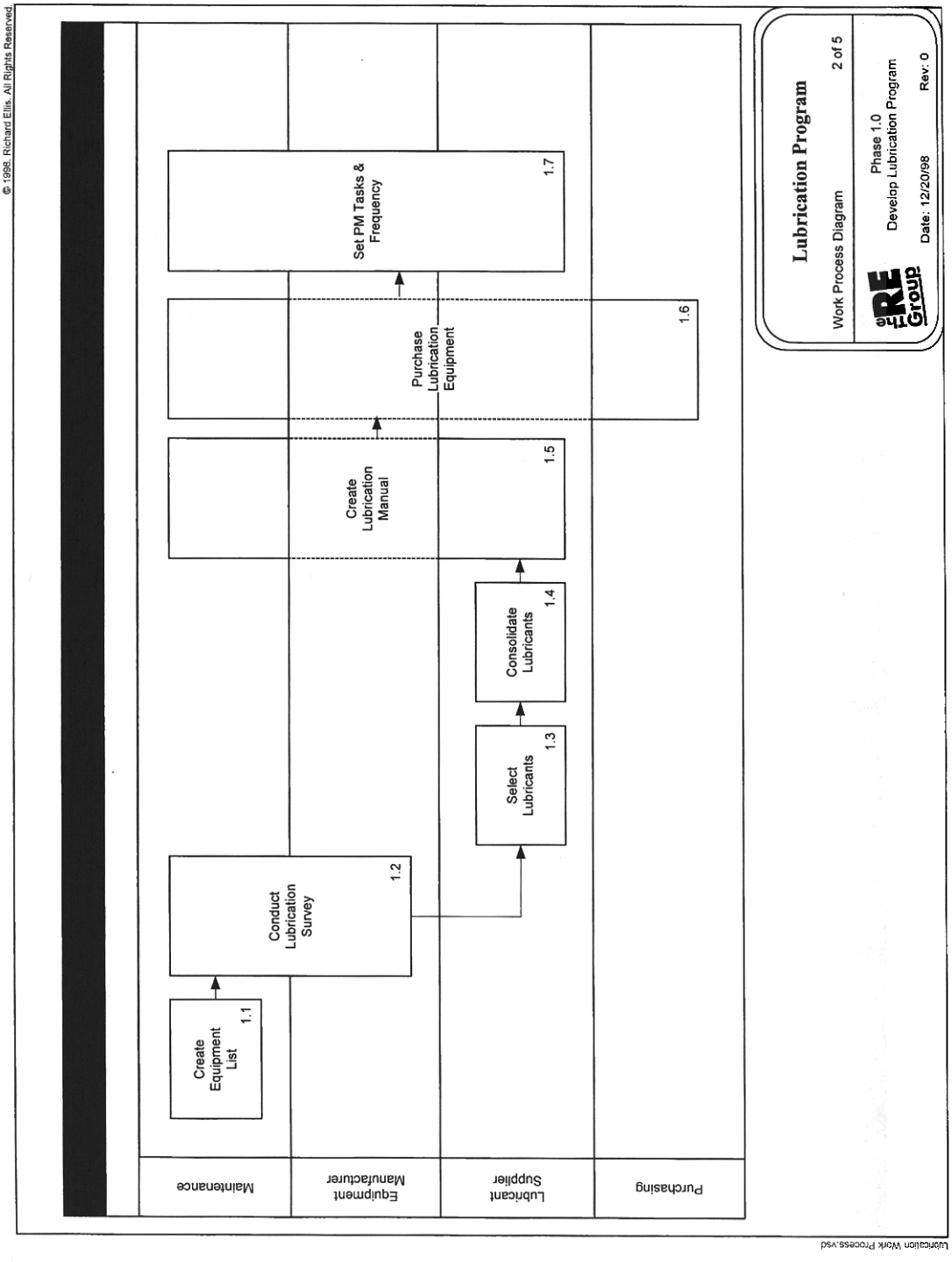

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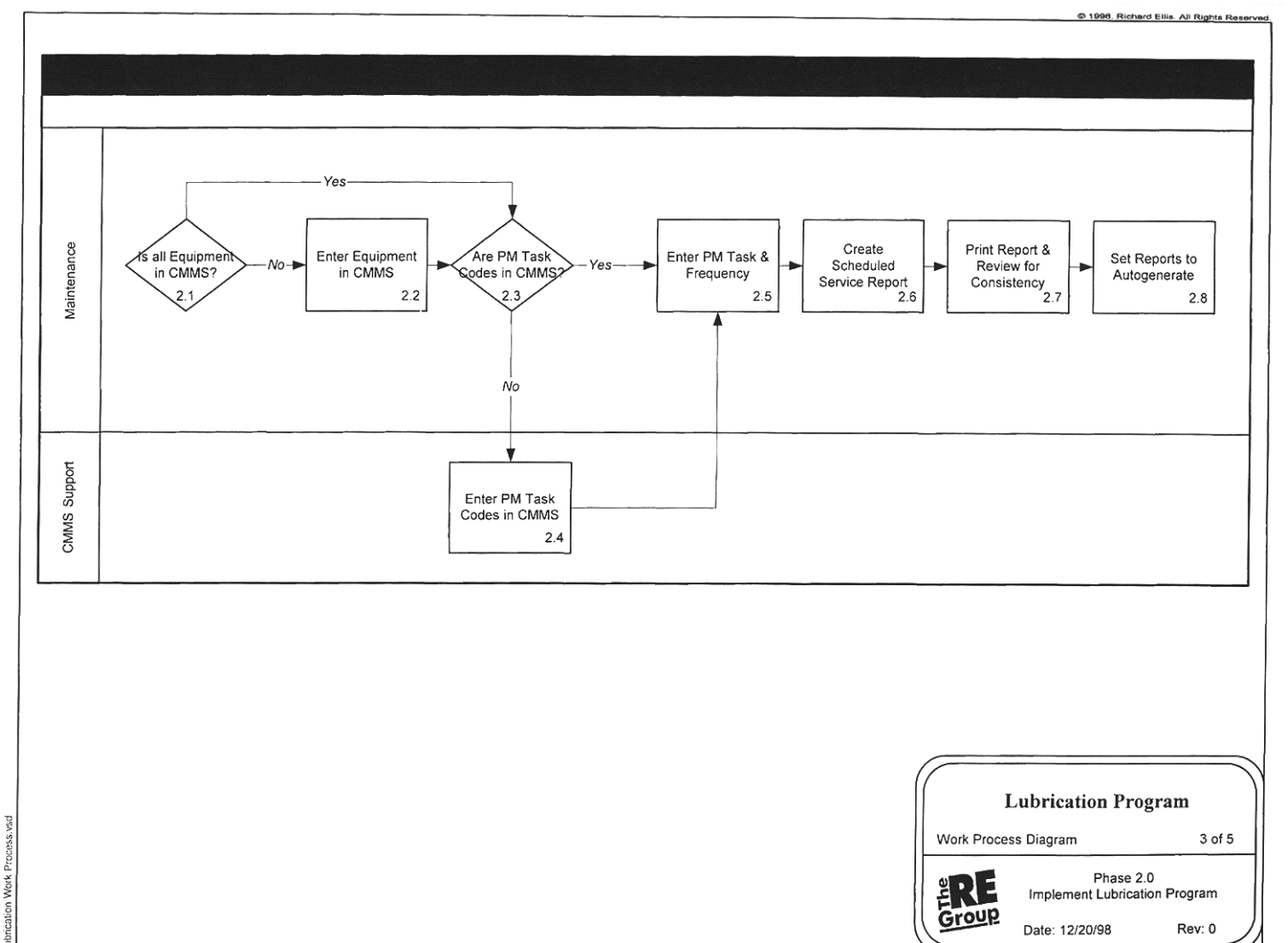

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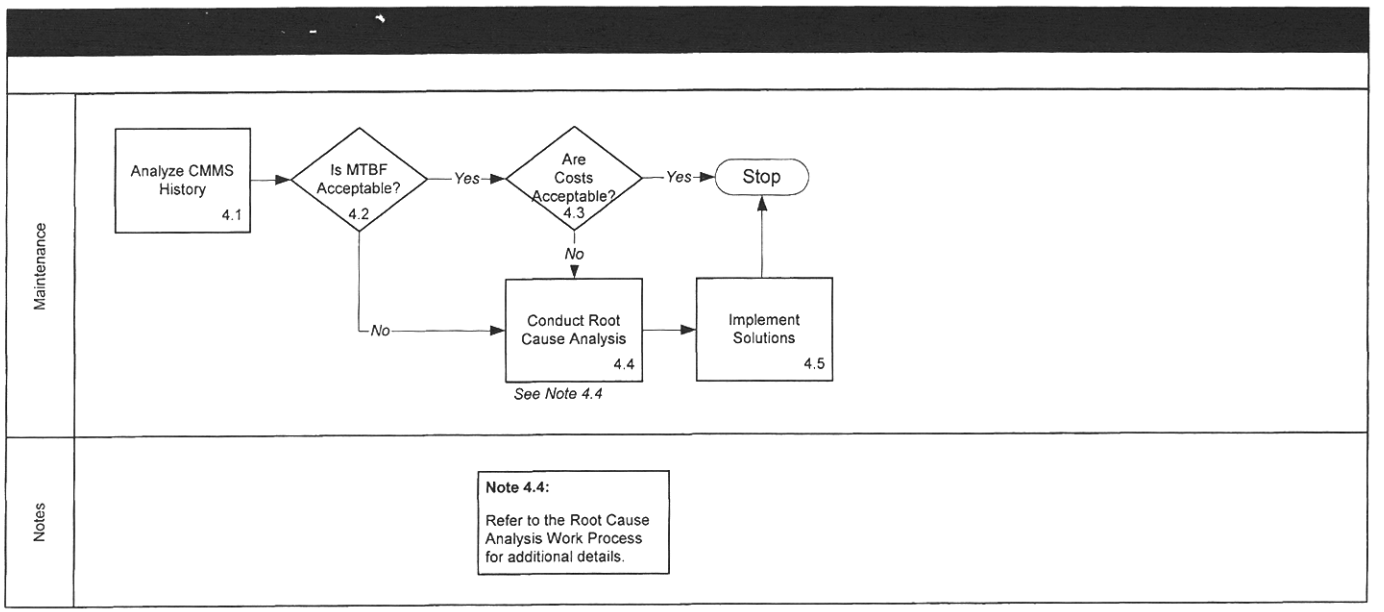

Lubrication Work Process.vsd

Lubrication Program

Work Process Diagram 5 of 5

The RE Group

Phase 4.0
Improve Lubrication Program

Date: 12/20/98 Rev: 0

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Appendix B

- Temperature Conversion Table
- Viscosity Index Charts
- ASTM Viscosity Blending Chart
- Approximate Color Scale Equivalents
- Representative Masses of Petroleum Products
- Abridged Gravity, Volume, and Mass Conversion Table
- Miscellaneous Conversion Factors

Temperature Conversion Tables

Locate in the center column of the three columns the temperature in °C or °F to be converted. For given Celsius temperatures, read Fahrenheit equivalent in the left-hand column. For given Fahrenheit temperatures, read the Celsius equivalent in the right-hand column.

Examples: (a) Given −30°C; convert to Fahrenheit. Locate −30 in the center column; read −22.0°F in the left-hand column. (b) Given −30°F; convert to Celsius. Locate −30 in the center column; read −34.4°C in the right-hand column.

For temperatures not shown, interpolate from the values listed, or use the following equations:

Celsius to Fahrenheit: °C x 9/5 + 32 = °F

Fahrenheit to Celsius: (°F − 32) x 5/9 = °C

°F	°C or °F	°C	°F	°C or °F	°C
−148.0	−100	− 73.3	+ 23.0	− 5	− 20.6
−130.0	− 90	− 67.8	+ 24.8	− 4	− 20.0
−112.0	− 80	− 62.2	+ 26.6	− 3	− 19.4
− 94.0	− 70	− 56.7	+ 28.4	− 2	− 18.9
− 76.0	− 60	− 51.1	+ 30.2	− 1	− 18.3
− 58.0	− 50	− 45.6	+ 32.0	0	− 17.8
− 54.4	− 48	− 44.4	+ 33.8	+ 1	− 17.2
− 50.8	− 46	− 43.3	+ 35.6	+ 2	− 16.7
− 47.2	− 44	− 42.2	+ 37.4	+ 3	− 16.1
− 43.6	− 42	− 41.1	+ 39.2	+ 4	− 15.6
− 40.0	− 40	− 40.0	+ 41.0	+ 5	− 15.0
− 36.4	− 38	− 38.9	+ 42.8	+ 6	− 14.4
− 32.8	− 36	− 37.8	+ 44.6	+ 7	− 13.9
− 29.2	− 34	− 36.7	+ 46.4	+ 8	− 13.3
− 25.6	− 32	− 35.6	+ 48.2	+ 9	− 12.8
− 22.0	− 30	− 34.4	+ 50.0	+ 10	− 12.2
− 18.4	− 28	− 33.3	+ 51.8	+ 11	− 11.7
− 14.8	− 26	− 32.2	+ 53.6	+ 12	− 11.1
− 11.2	− 24	− 31.1	+ 55.4	+ 13	− 10.6
− 7.6	− 22	− 30.0	+ 57.2	+ 14	− 10.0
− 4.0	− 20	− 28.9	+ 59.0	+ 15	− 9.4
− 0.4	− 18	− 27.8	+ 60.8	+ 16	− 8.9
+ 3.2	− 16	− 26.7	+ 62.6	+ 17	− 8.3
+ 6.8	− 14	− 25.6	+ 64.4	+ 18	− 7.8
+ 10.4	− 12	− 24.4	+ 66.2	+ 19	− 7.2
+ 14.0	− 10	− 23.3	+ 68.0	+ 20	− 6.7
+ 15.8	− 9	− 22.8	+ 69.8	+ 21	− 6.1
+ 17.6	− 8	− 22.2	+ 71.6	+ 22	− 5.6
+ 19.4	− 7	− 21.7	+ 73.4	+ 23	− 5.0
+ 21.2	− 6	− 21.1	+ 75.2	+ 24	− 4.4

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Temperature Conversion Tables

°F	°C or °F	°C	°F	°C or °F	°C
+ 77.0	+ 25	− 3.9	+158.0	+ 70	+ 21.1
+ 78.8	+ 26	− 3.3	+159.8	+ 71	+ 21.7
+ 80.6	+ 27	− 2.8	+161.6	+ 72	+ 22.2
+ 82.4	+ 28	− 2.2	+163.4	+ 73	+ 22.8
+ 84.2	+ 29	− 1.7	+165.2	+ 74	+ 23.3
+ 86.0	+ 30	− 1.1	+167.0	+ 75	+ 23.9
+ 87.8	+ 31	− 0.6	+168.8	+ 76	+ 24.4
+ 89.6	+ 32	0.0	+170.6	+ 77	+ 25.0
+ 91.4	+ 33	+ 0.6	+172.4	+ 78	+ 25.6
+ 93.2	+ 34	+ 1.1	+174.2	+ 79	+ 26.1
+ 95.0	+ 35	+ 1.7	+176.0	+ 80	+ 26.7
+ 96.8	+ 36	+ 2.2	+177.8	+ 81	+ 27.2
+ 98.6	+ 37	+ 2.8	+179.6	+ 82	+ 27.8
+100.4	+ 38	+ 3.3	+181.4	+ 83	+ 28.3
+102.2	+ 39	+ 3.9	+183.2	+ 84	+ 28.9
+104.0	+ 40	+ 4.4	+185.0	+ 85	+ 29.4
+106.8	+ 41	+ 5.0	+186.8	+ 86	+ 30.0
+107.6	+ 42	+ 5.6	+188.6	+ 87	+ 30.6
+109.4	+ 43	+ 6.1	+190.4	+ 88	+ 31.1
+111.2	+ 44	+ 6.7	+192.2	+ 89	+ 31.7
+113.0	+ 45	+ 7.2	+194.0	+ 90	+ 32.2
+114.8	+ 46	+ 7.8	+195.8	+ 91	+ 32.8
+116.6	+ 47	+ 8.3	+197.6	+ 92	+ 33.3
+118.4	+ 48	+ 8.9	+199.4	+ 93	+ 33.9
+120.2	+ 49	+ 9.4	+201.2	+ 94	+ 34.4
+122.0	+ 50	+ 10.0	+203.0	+ 95	+ 35.0
+123.8	+ 51	+ 10.6	+204.8	+ 96	+ 35.6
+125.6	+ 52	+ 11.1	+206.6	+ 97	+ 36.1
+127.4	+ 53	+ 11.7	+208.4	+ 98	+ 36.7
+129.2	+ 54	+ 12.2	+210.2	+ 99	+ 37.2
+131.0	+ 55	+ 12.8	+212.0	+100	+ 37.8
+132.8	+ 56	+ 13.3	+213.8	+101	+ 38.3
+134.6	+ 57	+ 13.9	+215.6	+102	+ 38.9
+136.4	+ 58	+ 14.4	+217.4	+103	+ 39.4
+138.2	+ 59	+ 15.0	+219.2	+104	+ 40.0
+140.0	+ 60	+ 15.6	+221.0	+105	+ 40.6
+141.8	+ 61	+ 16.1	+222.8	+106	+ 41.1
+143.6	+ 62	+ 16.7	+224.6	+107	+ 41.7
+145.4	+ 63	+ 17.2	+226.4	+108	+ 42.2
+147.2	+ 64	+ 17.8	+228.2	+109	+ 42.8
+149.0	+ 65	+ 18.3	+230.0	+110	+ 43.3
+150.8	+ 66	+ 18.9	+231.8	+111	+ 43.9
+152.6	+ 67	+ 19.4	+233.6	+112	+ 44.4
+154.4	+ 68	+ 20.0	+235.4	+113	+ 45.0
+156.2	+ 69	+ 20.6	+237.2	+114	+ 45.6

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Temperature Conversion Tables

°C or °F			°C or °F		
°F		°C	°F		°C
+239.0	+115	+ 46.1	+392.0	+200	+ 93.3
+240.8	+116	+ 46.7	+395.6	+202	+ 94.4
+242.6	+117	+ 47.2	+399.2	+204	+ 95.6
+244.4	+118	+ 47.8	+402.8	+206	+ 96.7
+246.2	+119	+ 48.3	+406.4	+208	+ 97.8
+248.0	+120	+ 48.9	+410.0	+210	+ 98.9
+251.6	+122	+ 50.0	+413.6	+212	+100.0
+255.2	+124	+ 51.1	+417.2	+214	+101.1
+258.8	+126	+ 52.2	+420.8	+216	+102.2
+262.4	+128	+ 53.3	+424.4	+218	+103.3
+266.0	+130	+ 54.4	+428.0	+220	+104.4
+269.6	+132	+ 55.6	+437.0	+225	+107.2
+273.2	+134	+ 56.7	+446.0	+230	+110.0
+276.8	+136	+ 57.8	+455.0	+235	+112.8
+280.4	+138	+ 58.9	+464.0	+240	+115.6
+284.0	+140	+ 60.0	+473.0	+245	+118.3
+287.6	+142	+ 61.1	+482.0	+250	+121.1
+291.2	+144	+ 62.2	+491.0	+255	+123.9
+294.8	+146	+ 63.3	+500.0	+260	+126.7
+298.4	+148	+ 64.4	+509.0	+265	+129.4
+302.0	+150	+ 65.6	+518.0	+270	+132.2
+305.6	+152	+ 66.7	+527.0	+275	+135.0
+309.2	+154	+ 67.8	+536.0	+280	+137.8
+312.8	+156	+ 68.9	+545.0	+285	+140.6
+316.4	+158	+ 70.0	+554.0	+290	+143.3
+320.0	+160	+ 71.1	+563.0	+295	+146.1
+323.6	+162	+ 72.2	+572.0	+300	+148.9
+327.2	+164	+ 73.3	+590.0	+310	+154.4
+330.8	+166	+ 74.4	+608.0	+320	+160.0
+334.4	+168	+ 75.6	+626.0	+330	+165.6
+338.0	+170	+ 76.7	+644.0	+340	+171.1
+341.6	+172	+ 77.8	+662.0	+350	+176.7
+345.2	+174	+ 78.9	+680.0	+360	+182.2
+348.8	+176	+ 80.0	+698.0	+370	+187.8
+352.4	+178	+ 81.1	+716.0	+380	+193.3
+356.0	+180	+ 82.2	+734.0	+390	+198.9
+359.6	+182	+ 83.3	+752.0	+400	+204.4
+363.2	+184	+ 84.4	+932.0	+500	+260.0
+366.8	+186	+ 85.6	+1112.0	+600	+315.6
+370.4	+188	+ 86.7	+1292.0	+700	+371.1
+374.0	+190	+ 87.8	+1472.0	+800	+427.0
+377.6	+192	+ 88.9	+1652.0	+900	+482.0
+381.2	+194	+ 90.0	+1832.0	+1000	+538.0
+384.8	+196	+ 91.1	+2012.0	+1100	+593.0
+388.4	+198	+ 92.2	+2192.0	+1200	+649.0

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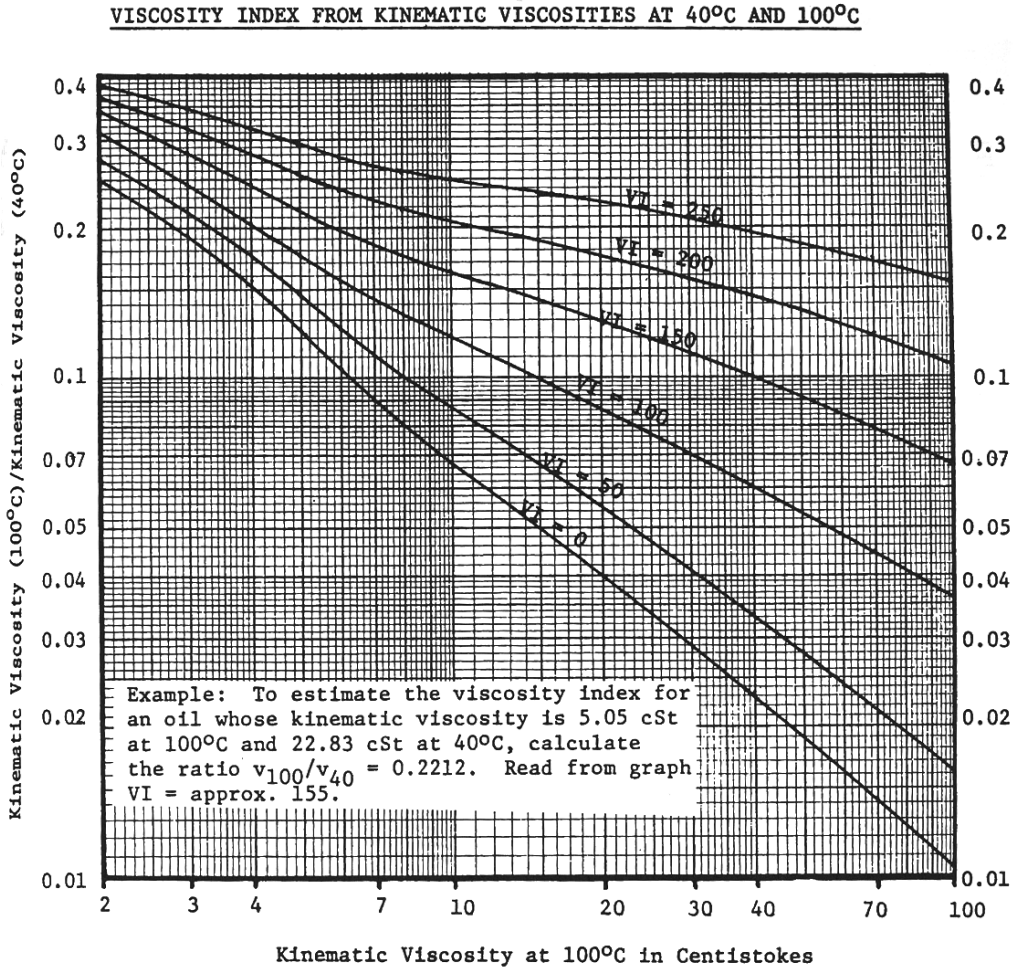

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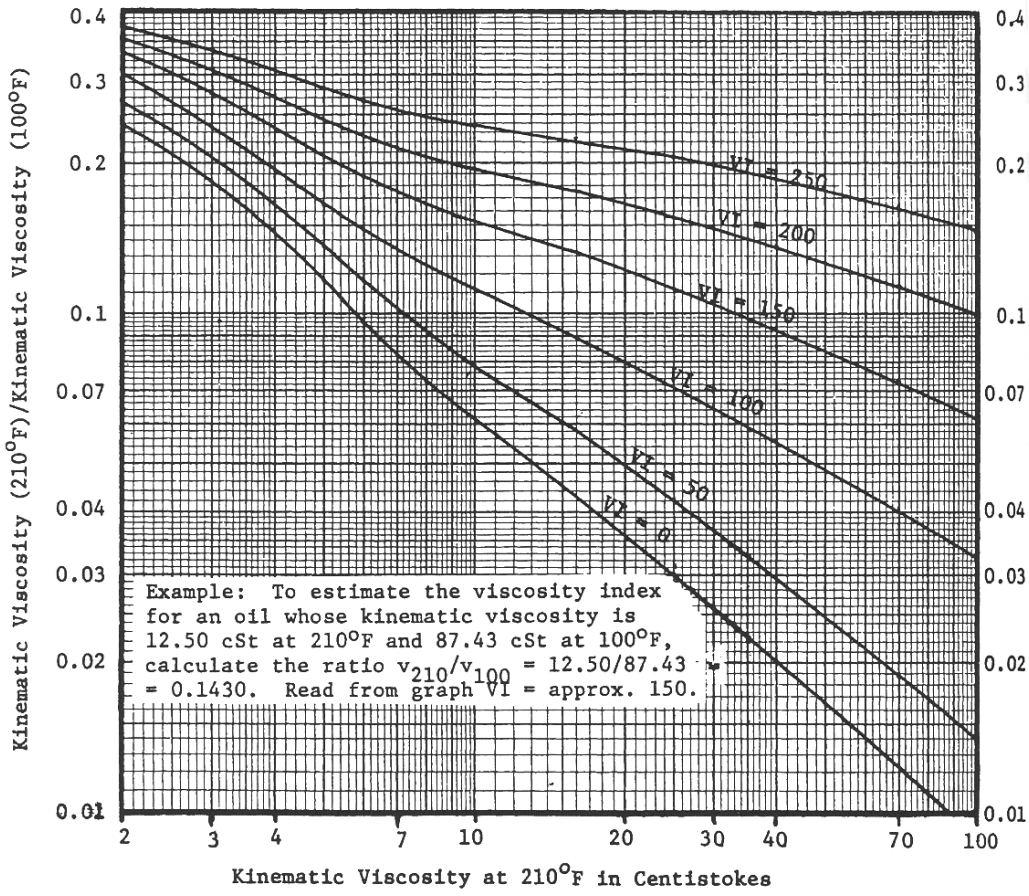
VISCOSITY INDEX FROM KINEMATIC VISCOSITIES AT 100°F AND 210°F



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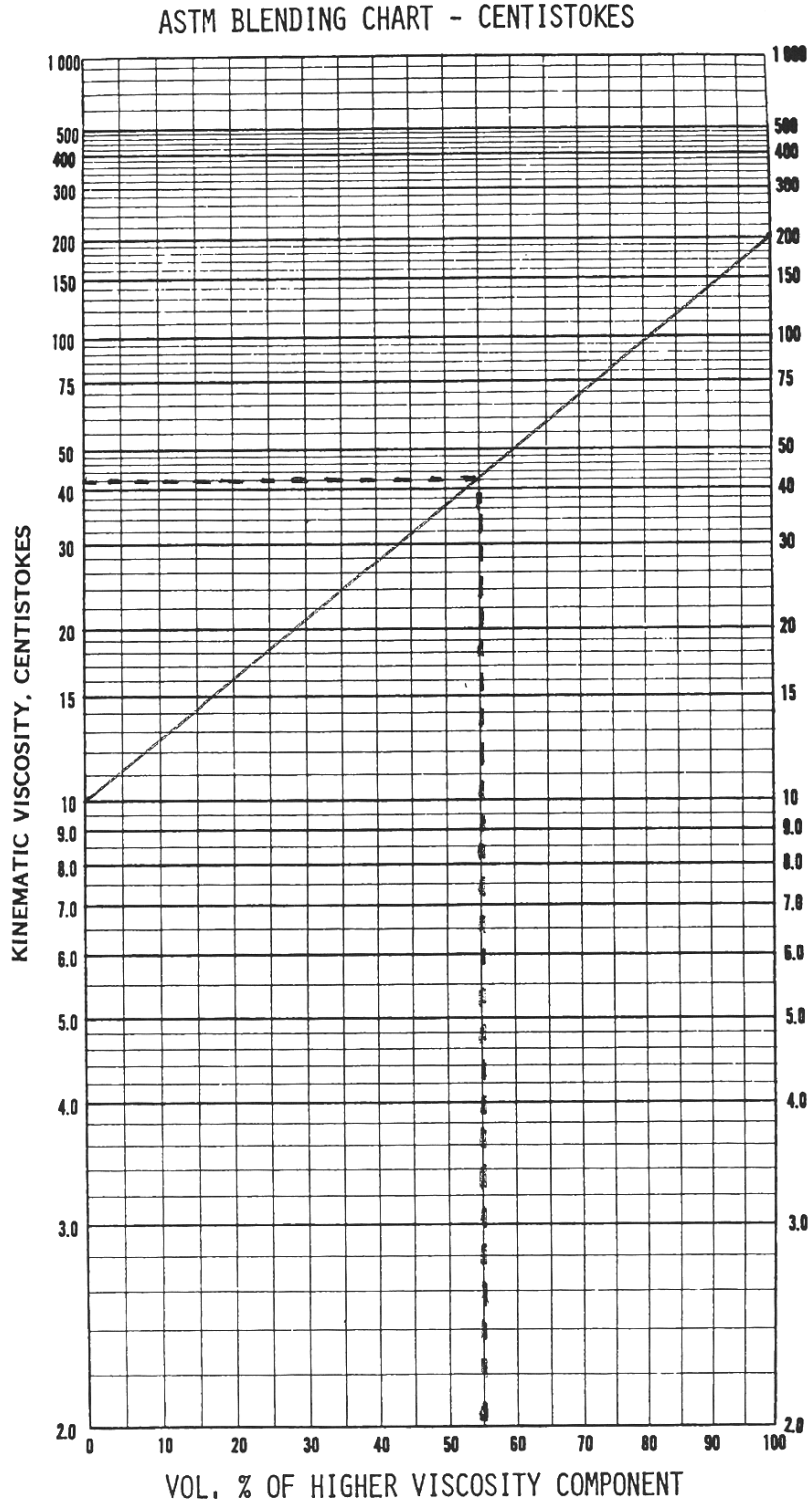

Example: Higher viscosity component has 300 cSt viscosity, lower viscosity component has 10 cSt viscosity. Desired blend should have 42 cSt viscosity. Answer: Use 54%, by volume, of higher viscosity component.

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Approximate Color Scale Equivalents

DIN 51-578* ASTM D 1500	TAG-Robinson Colorimeter	Union (N.P.A.) Colorimeter (ASTM D 155)	N.P.A. Common Terms
0	22 3/4	—	—
0.5	21 1/2	1	Lily White
1.0	17 1/2	1 1/2	Cream White
1.5	13 1/2	1 3/4	—
2.0	11 3/4	2	Extra Pale
2.5	10 1/2	2 1/2	Extra Lemon Pale
3.0	9 3/4	3	Lemon Pale
3.5	9 1/2	3 1/2	Extra Orange Pale
4.0	9	3 3/4	Orange Pale
4.5	7	4 1/4	—
5.0	5 1/2	4 1/2	Pale
5.5	4 1/2	4 3/4	Light Red
6.0	3 1/4	5 1/2	
6.5	2 1/2	6	Dark Red
7.0	2	7	Claret Red
7.5	1 1/2	7 1/2	—
8.0	1	8	—

*Color scales for ASTM D 1500 and the German standard DIN 51-578 are the same.

Representative Masses of Petroleum Products

	kg/m³	m³/Mg	lb/U.S. gal	bbl/tonne
LPG	542	1.84	4.53	11.60
Aviation Gasoline	707	1.42	5.90	8.90
Motor Gasoline	740	1.35	6.18	8.50
Kerosine	812	1.23	6.77	7.75
Distilate Fuel Oil	843	1.19	7.04	7.46
Lubricating Oil	899	1.11	7.50	7.00
Residual Fuel Oil	944	1.06	7.88	6.66
Paraffin Wax	799	1.25	6.67	7.87
Grease	998	1.00	8.33	6.30
Asphalt	1038	0.96	8.66	6.06

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ABRIDGED GRAVITY, VOLUME, AND MASS CONVERSION TABLE

Approximate Conversions at 15°C Except Where Noted

Density 15°C kg/m³	Specific Gravity 60/60°F	API Gravity 60°F	dm³/Mg	U.S. gal/Mg	Barrels/Mg	Imp. gal/Mg
1075	1.0757	0.04	930.2	245.77	5.852	204.63
1050	1.0507	3.18	952.4	251.62	5.991	209.50
1025	1.0256	6.46	975.6	257.76	6.137	214.61
1000	1.0006	9.92	1000.0	264.20	6.291	219.97
990	0.9906	11.34	1010.1	266.87	6.354	222.20
980	0.9806	12.80	1020.4	269.59	6.419	224.46
970	0.9706	14.29	1030.9	272.37	6.485	226.78
960	0.9606	15.81	1041.7	275.21	6.553	229.14
950	0.9505	17.36	1052.6	278.11	6.622	231.55
940	0.9405	18.95	1063.8	281.06	6.692	234.01
930	0.9305	20.56	1075.3	284.09	6.764	236.53
920	0.9205	22.22	1087.0	287.17	6.838	239.10
910	0.9105	23.91	1098.9	290.33	6.913	241.73
900	0.9005	25.64	1111.1	293.56	6.989	244.42
890	0.8905	27.40	1123.6	296.85	7.068	247.16
880	0.8805	29.21	1136.4	300.23	7.148	249.97
870	0.8705	31.06	1149.4	303.68	7.231	252.84
860	0.8605	32.95	1162.8	307.21	7.315	255.78
850	0.8504	34.89	1176.5	310.82	7.401	258.79
840	0.8404	36.87	1190.5	314.52	7.489	261.87
830	0.8304	38.90	1204.8	318.31	7.579	265.03
820	0.8204	40.98	1219.5	322.20	7.671	268.26
810	0.8104	43.11	1234.6	326.17	7.766	271.57
800	0.8004	45.29	1250.0	330.25	7.863	274.97
790	0.7903	47.53	1265.8	334.43	7.963	278.45
780	0.7803	49.83	1282.1	338.72	8.065	282.02
770	0.7703	52.19	1298.7	343.12	8.170	285.68
760	0.7603	54.61	1315.8	347.63	8.277	289.44
750	0.7503	57.10	1333.3	352.27	8.387	293.30
725	0.7252	63.61	1379.3	364.41	8.677	303.41
700	0.7002	70.59	1428.6	377.43	8.986	314.25
675	0.6751	78.08	1481.5	391.41	9.319	325.89
650	0.6501	86.16	1538.5	406.46	9.678	338.42
625	0.6251	94.88	1600.0	422.72	10.065	351.96
600	0.6000	—	1666.7	440.33	10.484	366.62

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MASS CONVERSIONS

	mg	g	lb	kg	short ton	Mg (tonne)
mg	1	0.001	0.000 002	0.000 001	———	———
g	1 000.0	1	0.002 205	0.001	———	———
lb	453 592.4	453.592 4	1	0.453 592	0.000 5	0.000 454
kg	1 000 000	1 000.0	2.204 623	1	0.001 102	0.001
short ton	———	———	2 000.0	907.184 7	1	0.907 185
Mg (tonne)	———	———	2 204.623	1 000.0	1.102 311	1

VOLUME CONVERSIONS

	U.S. qt	dm^3 (litre)	U. S. gal	Imp. gal	Barrel	m^3 (kL)
U.S. qt	1	0.946 353	0.25	0.208 168	0.005 952	0.000 946
dm^3 (litre)	1.056 688	1	0.264 172	0.219 969	0.006 290	0.001
U.S. gal	4.0	3.785 412	1	0.832 674	0.023 810	0.003 785
Imp. gal	4.803 802	4.546 092	1.200 950	1	0.028 594	0.004 546
Barrel	168.0	158.987 3	42.0	34.972 30	1	0.158 987
m^3 (kL)	1 056.688	1 000.0	264.172 0	219.969 2	6.289 811	1

PRESSURE CONVERSIONS

	mm Hg	in. H_2O	kPa	psi	kg/cm^2	atm.
mm Hg	1	0.535 776	0.133 322	0.019 337	0.001 360	0.001 316
in. H_2O	1.866 453	1	0.248 84	0.036 091	0.002 537	0.002 456
kPa	7.500 615	4.018 647	1	0.145 038	0.010 197	0.009 869
psi	51.714 92	27.707 59	6.894 757	1	0.070 307	0.068 046
kg/cm^2	735.559 1	394.094 6	98.066 50	14.223 34	1	0.967 841
atm.	760.0	407.189 4	101.325 0	14.695 95	1.033 227	1

POWER CONVERSIONS

	W	hp	kW	Btu/s	kcal/s	MW
W	1	0.001 341	0.001	0.000 948	0.000 239	0.000 001
hp	745.699 9	1	0.745 700	0.706 787	0.178 227	0.000 746
kW	1 000.0	1.341 022	1	0.947 817	0.239 006	0.001
Btu/s	1 055.056	1.414 853	1.055 056	1	0.252 164	0.001 055
kcal/s	4 184.0	5.610 836	4.184	3.965 666	1	0.004 184
MW	1 000 000	1 341.022	1 000.0	947.817 0	239.005 7	1

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ENERGY, WORK CONVERSIONS

	kJ	Btu①	kcal②	MJ	hp·h	kW·h
kJ	1	0.947 817	0.239 006	0.001	0.000 373	0.000 278
Btu	1.055 056	1	0.252 164	0.001 055	0.000 393	0.000 293
kcal	4.184 0	3.965 666	1	0.004 184	0.001 559	0.001 162
MJ	1 000.0	947.817 0	239.005 7	1	0.372 506	0.277 778
hp·h	2 684.520	2 544.434	641.615 7	2.684 520	1	0.745 700
kW·h	3 600.0	3 412.141	860.420 7	3.60	1.341 022	1

① International Table
② Thermochemical

LENGTH CONVERSIONS

	mm	cm	in.	ft	m	km	mile
mm	1	0.1	0.039 370	0.003 281	0.001	0.000 001	———
cm	10.0	1	0.393 701	0.032 808	0.01	0.000 01	———
in.	25.4	2.54	1	0.083 333	0.0254	0.000 025	———
ft	304.8	30.48	12.0	1	0.304 8	0.000 305	0.000 189
m	1 000.0	100.0	39.370 08	3.280 840	1	0.001	0.000 621
km	1 000 000	100 000.0	39 370.08	3 280.840	1 000.0	1	0.621 371
mile	———	———	63 360.0	5 280.0	1 609.344	1.609 344	1

AREA CONVERSIONS

	mm^2	cm^2	$in.^2$	ft^2	m^2	acre	ha
mm^2	1	0.01	0.001 550	0.000 011	0.000 001	———	———
cm^2	100.0	1	0.155 000	0.001 076	0.000 1	———	———
$in.^2$	645.16	6.451 6	1	0.006 944	0.000 645	———	———
ft^2	92 903.04	929.030 4	144.0	1	0.092 903	0.000 023	0.000 009
m^2	1 000 000	10 000.0	1 550.003	10.763 91	1	0.000 247	0.000 1
acre	———	———	———	43 560.0	4 046.856	1	0.404 686
ha	———	———	———	107 639.1	10 000.0	2.471 054	1

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SAE J300

Rev. March 1993

SAE VISCOSITY GRADES FOR ENGINE OILS[1]

SAE Viscosity Grade	Low-Temperature (°C) Cranking Viscosity[2], cP Max	Low-Temperature (°C) Pumping Viscosity,[3] cP Max With No Yield Stress	Kinematic Viscosity[4] (cSt) at 100 °C Min	Kinematic Viscosity[4] (cSt) at 100 °C Max	High-Shear Viscosity[5] (cP) at 150 °C and 10^6 & [1] Min
0W	3250 at -30	30 000 at -35	3.8	—	—
5W	3500 at -25	30 000 at -30	3.8	—	—
10W	3500 at -20	30 000 at -25	4.1	—	—
15W	3500 at -15	30 000 at -20	5.6	—	—
20W	4500 at -10	30 000 at -15	5.6	—	—
25W	6000 at -5	30 000 at -10	9.3	—	—
20	—	—	5.6	<9.3	2.6
30	—	—	9.3	<12.5	2.9
40	—	—	12.5	<16.3	2.9 (0W-40, 5W-40, and 10W-40 grades)
40	—	—	12.5	<16.3	3.7 (15W-40, 20W-40, 25W-40, 40 grades)
50	—	—	16.3	<21.9	3.7
60	—	—	21.9	<26.1	3.7

Note — 1 cP = 1 mPa's; 1 cSt = 1 mm^2/s

[1] All values are critical specifications as defined by ASTM D 3244

[2] ASTM D 5293

[3] ASTM D 4684 Note that the presence of any yield stress detectable by this method constitutes a failure regardless of viscosity.

[4] ASTM D 445

[5] ASTM D 4683, CEC L-36-A-90 (ASTM D 4741)

SAE J306

Rev. October 1991

SAE Gear Viscosity Grades Axle and Manual Transmission Lubricants

	70W	75W	80W	85W	90	140	250
Viscosity at 100°C							
Min. (cSt)	4.1	4.1	7.0	11.0	13.5	24.0	41.0
Max. (cSt)	No requirements				<24.0	<41.0	No req
Viscosity at 150,000 cP							
Max. Temp. °C	-55	-40	-26	-12	No requirements		

MIL-L-2105D

	75W	80W-90	85W-140
Viscosity at 100°C			
Min. (cSt)	4.1	13.5	24.0
Max. (cSt)	—	<24.0	<41.0
Viscosity at 150,000 cP Max. Temp. °C	-40	-26	-12
Channel Point, Min. °C	-45	-35	-20
Flash Point, Min. °C	150	165	180

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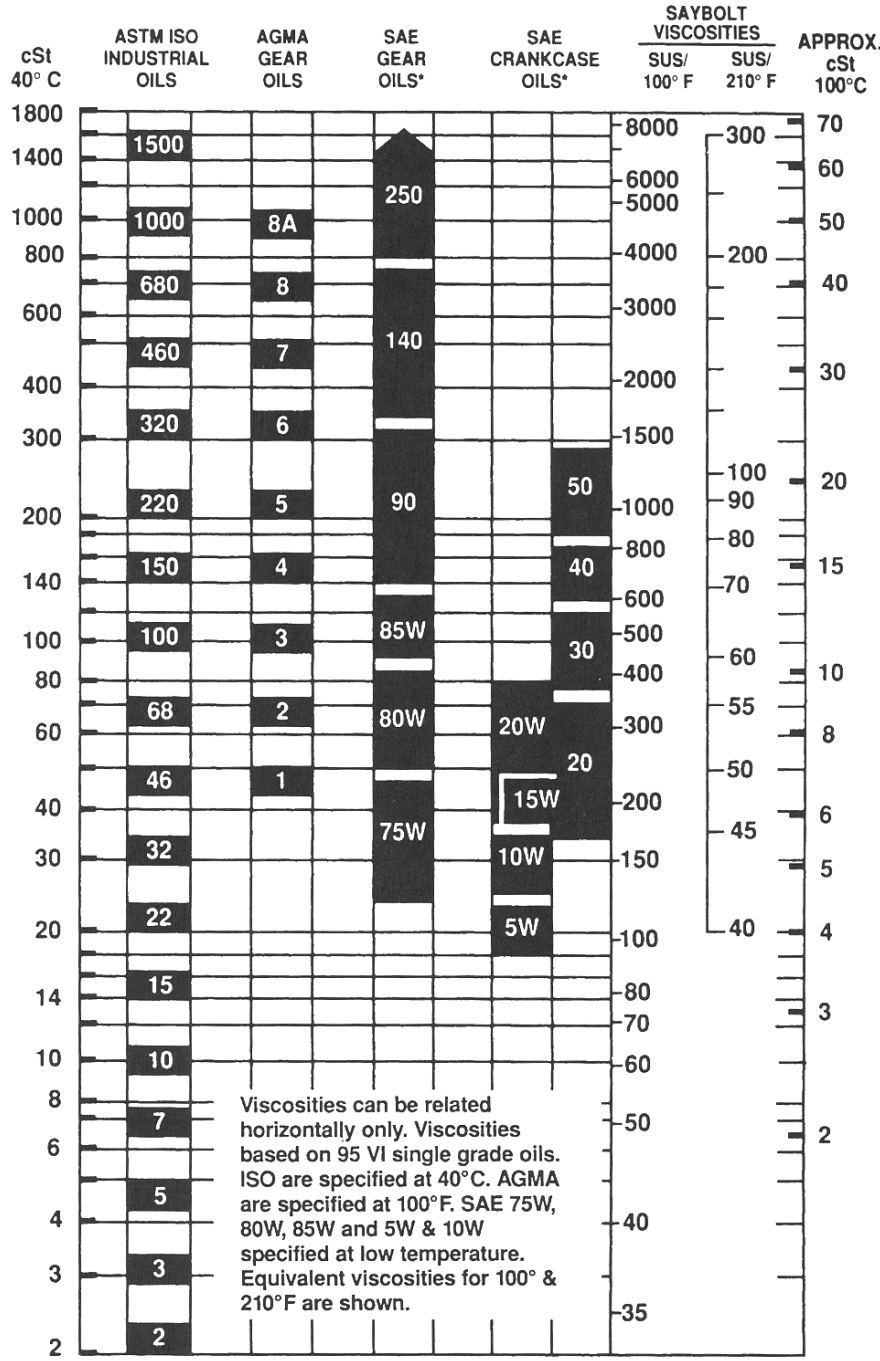
Approximate Equivalence of Viscosity Grading Systems



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COMPARATIVE VISCOSITY CLASSIFICATIONS

	ISO Viscosity Grade								
	22	32	46	68	100	150	220	320	460
Vis. @ 40° C									
Min. cSt	19.8	28.8	41.4	61.2	90	135	198	288	414
Max. cSt	24.2	35.2	50.6	74.8	110	165	242	352	506
Vis. @ 100° F									
Min. SUS	96	135	191	280	410	615	900	1310	1880
Max. SUS	115	164	234	345	500	750	1110	1600	2300
Vis. @ 100°C	←			No Requirement*					→
Min. cSt	4.0	4.97	6.22	7.96	10.30	13.56	17.50	22.40	28.30
Max. cSt	4.5	5.61	7.05	9.09	11.82	15.51	19.96	25.50	32.30

	AGMA Lubricant Number						
	1	2	3	4	5	6	7
Vis. @ 40° C							
Min. cSt	41.4	61.2	90	135	198	288	414
Max. cSt	50.6	74.8	110	165	242	352	506
Vis. @ 100° C							
Min. SUS	193	284	417	626	918	1335	1919
Max. SUS	235	347	510	765	1122	1632	2346
Vis. @ 100° C	←		No Requirement*				→
Min. cSt	6.22	7.96	10.30	13.56	17.50	22.40	28.30
Max. cSt	7.05	9.09	11.82	15.51	19.96	25.50	32.30

*Viscosities given are not required; however, for "informational purposes," viscosities listed are calculated assuming an oil with a V.I. of 95.

ABBREVIATIONS – INDUSTRY STANDARDS

AGMA	American Gear Manufacturers Association
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
CCMC	Comité des Constructeurs d'Automobiles du Marché Commun
CID	Commercial Item Description (U.S. Military)
ILSAC	International Lubricant Standardization and Approval Committee
JASO	Japanese Automobile Standards Organization
NLGI	National Lubricating Grease Institute
NMMA	National Marine Manufacturers Association
SAE	Society of Automotive Engineers
STLE	Society of Tribologists and Lubrication Engineers

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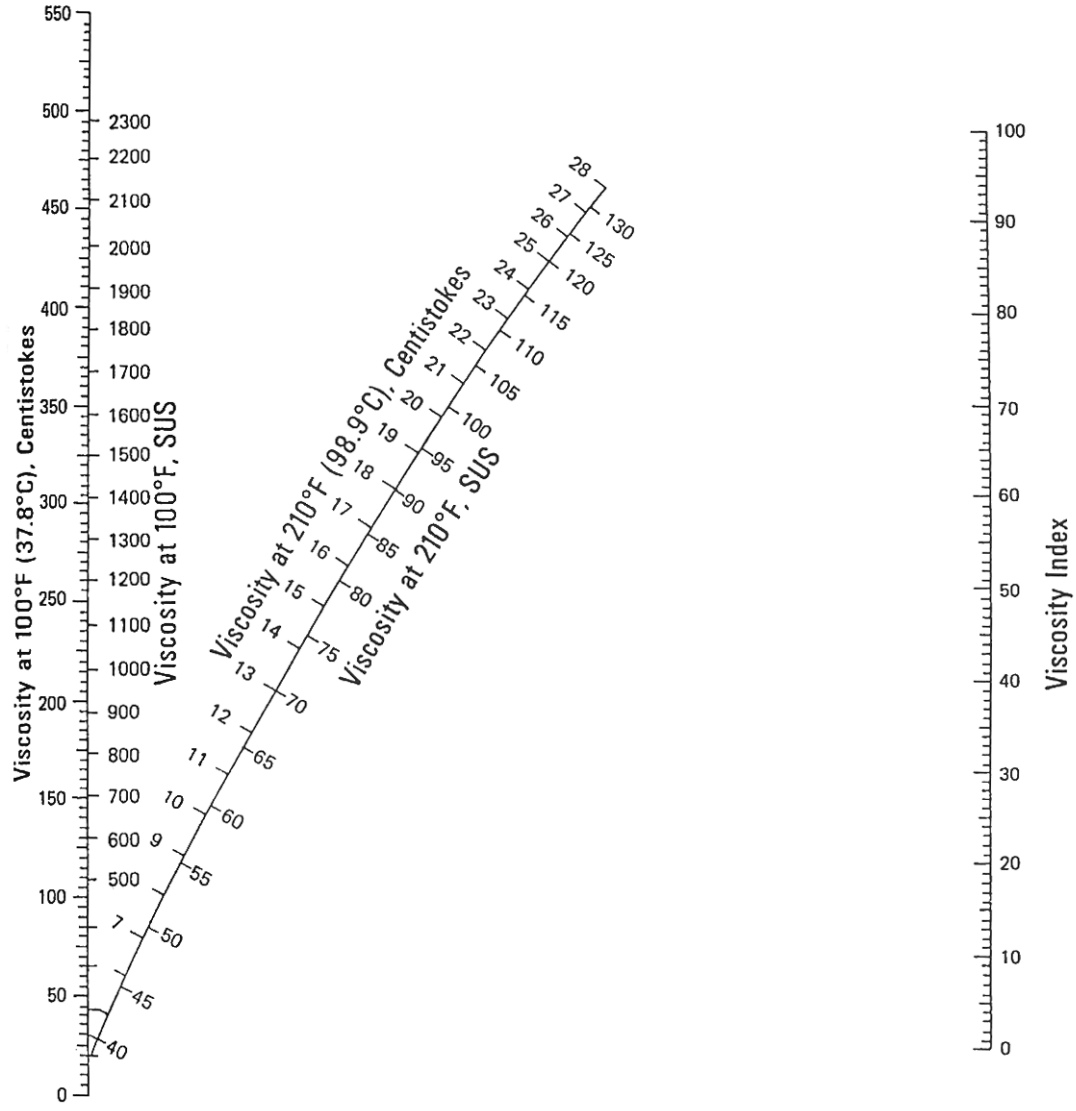
Viscosity Index, 0-100


Viscosity at 100°F (37.8°C), Centistokes
Viscosity at 100°F, SUS
Viscosity at 210°F (98.9°C), Centistokes
Viscosity at 210°F, SUS
Viscosity Index

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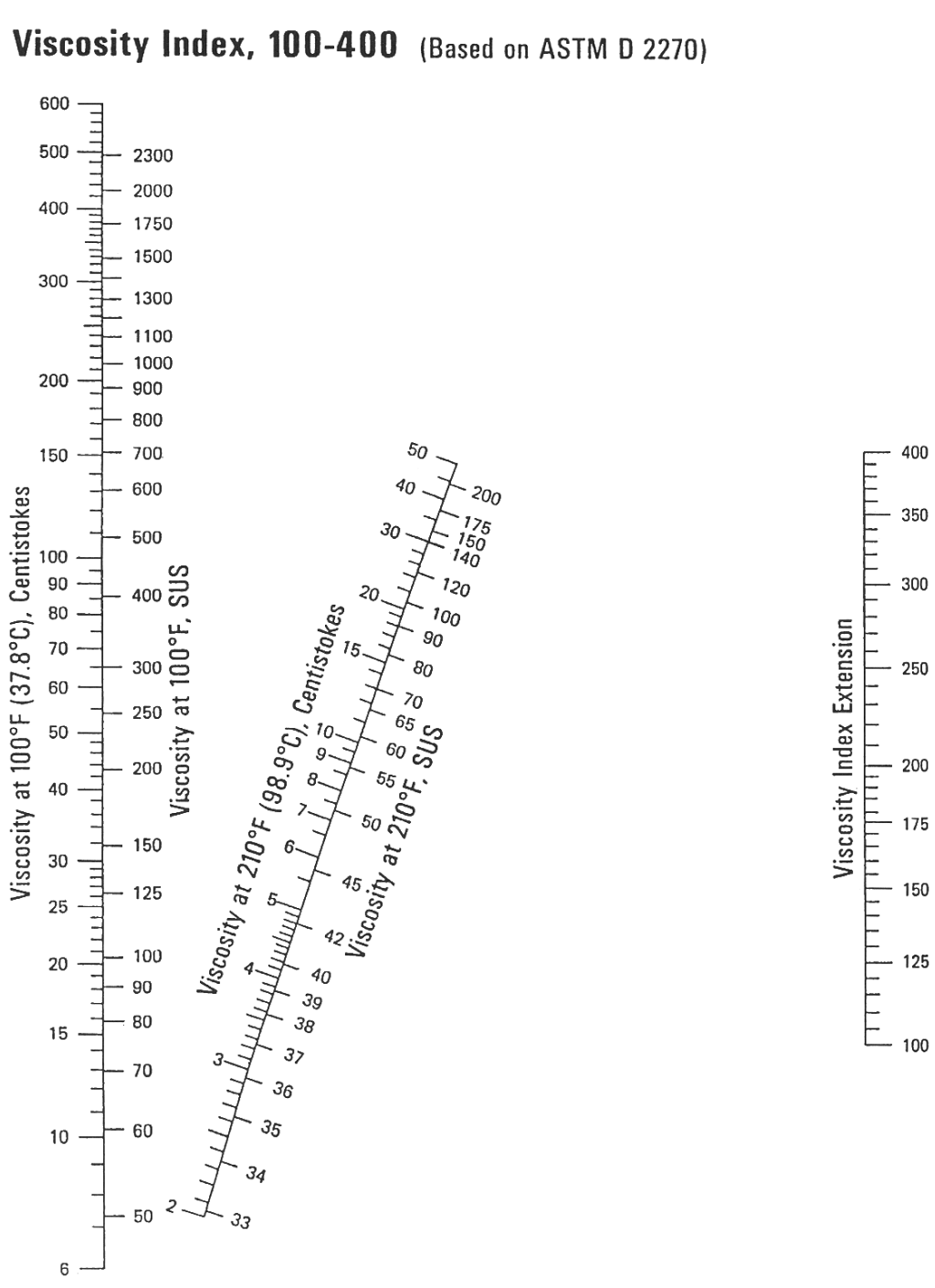

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